REMARKS

Reconsideration is respectfully requested.

Status of the Claims

Claims 1 - 37 are currently pending in the present application. Claims 7, 8, 15, 16, 18, 19, and 22 are canceled without prejudice or disclaimer, and claims 1, 2, 5, 6, 9 - 14, 17, 20, 21 and 31 are amended. No new matter is introduced. Support for the amendments may be found, for example, with reference to Applicant's specification at page 7, lines 7 - 13, page 10, lines 18 - 20 and page 19, line 19 - page 20, line 1.

Rejection under 35 U.S.C. § 103

Claims 1 - 37 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Japanese Patent Publication No. 3-237088 to Nippon Mining Co. ("the '088 Publication") in view of Japanese Patent Publication No. 2000-313699 to Japan Energy Corp. ("the '699 Publication") and Japanese Patent Publication No. 3-40987 to Nippon Telephone & Telegraph Corp ("the '087 Publication"). Claims 17 - 21, 25 and 26 are rejected under 35 U.S.C. § 103(a) as being unpatentable over the '087 Publication in view of P. Rudolph, "Studies on interface curvature during vertical Bridgman growth of InP in a flat-bottom container," Journal of Crystal Growth, 1996, Vol. 158, pp 43 - 48 ("Rudolph"). Claims 22 - 24 are rejected under 35 U.S.C. § 103(a) as being unpatentable over the '088 Publication in view of the '087 Publication. Claims 27 - 29 are rejected under 35 U.S.C. § 103(a) as being unpatentable over the '087 Publication. Claims 30 and 31 are rejected under 35 U.S.C. § 103(a) as being unpatentable over Rudolph. Claims 32- 37 are rejected under 35 U.S.C. § 103(a) as being unpatentable over the '087 Publication in view of the '088 Publication and the '699 Publication.

As claims 7, 8, 15, 16, 18, 19 and 22 have been canceled without prejudice or disclaimer, Applicant submits that the rejections as to claims 7, 8, 15, 16, 18, 19 and 22 are moot. Applicant amend claims 1, 2, 5, 6, 9 - 14, 17, 20, 21 and 31 to further clarify the nature of their invention, and

respectfully traverse the rejections of claims 1- 6, 9 - 14, 17, 20, 21 and 23 - 37 under 35 U.S.C. § 103(a).

In amended independent claim 1, Applicant claims:

1. An indium phosphide substrate containing iron or tin as a dopant, comprising:

an average dislocation density value of a wafer being less than 5000 cm^{-2};

a ratio of the difference between a maximum value and a minimum value with respect to an average value of dopant concentration in said wafer being 30% or less;

<u>a substantially uniform distribution of said dopant concentration in the depth direction of said wafer</u>.

(Emphasis added

The Examiner suggests that the '088 Publication is directed to addressing "the technical issue for obtaining a high-quality InP single crystal, comprising applying the means of making the density of foreign matter uniform throughout the crystal through heat treatment as further taught in [the '699 Publication]. Applicant respectfully disagrees.

The '699 Publication discloses:

A method for making a semi-insulating InP crystal characterized by vacuum-sealing in an ampule an InP single crystal, phosphorus, and a foreign matter, other than InP, desired to be added to the InP single crystal, the foreign matter being in an elementary form, a compound form with phosphorus, or both, and performing heat treatment under a condition of partial pressure less than 6 atm, preferably 1 to 5 atm, and more preferably 1 to 3 atm.

(see, e.g., claim 1 of the'699 Publication).

At paragraph [0017], the '699 Publication goes on to describe the advantages of the disclosed method as follows:

> According to the method for making the InP single crystal of the present invention, a desired foreign matter can be uniformly added to the InP single crystal at a relatively low production cost, and the semi-insulating property can be realized even when the Fe concentration is low, i.e., 0.03 to 0.1 ppmw. Thus, there is also an advantage that a semi-insulating InP substrate with excellent device characteristics can be fabricated.

Applicant submits however that the '699 Publication fails to demonstrate that an indium phosphide crystal with a low dislocation density has been obtained by this process. FIGs. 4 and 5 of the '699 Publication show resistivity, not the dopant concentration which is treated by the present invention. One having skill in the art will understand that uniformity in resistivity does not necessarily indicate uniformity in dopant concentration, as resistivity is also a function of the concentration of impurities other than the dopant and the thermal history of the crystal. In paragraph [0015], for example, it is disclosed that a "variation in resistivity [in a radial direction along] the surface was about 10%," while no disclosure is provide with regard to the uniformity of dopant concentrations. Moreover, the '699 Publication does not even appear to teach uniform resistivity, as the maximum and minimum values (5×10^7 Ωcm, 2.5×10^7 Ωcm) shown in FIG. 4 vary by 33% in relation to an average resistivity value (3.75) x 10^7 Ωcm.

At paragraph [0016], the '699 Publication teaches that "[as] for the measurement method, the resistivity in depth direction of the InP substrate was measured by repeating lapping and electrical measurement every 50 μm. As a result, it was found that the resistivity of the InP after the heat treatment shows a semi-insulating property up to near the center of the substrate [in the depth direction], and it can be considered that Fe atoms diffused to near the substrate center." No further description is provided as to uniformity of dopant concentration. While electrical properties according to the Van der Pauw method are disclosed, Applicant submits that one skilled in the art would recognize that a resistivity distribution in the depth direction cannot be accurately measured by the Van der Pauw method. While FIG. 5 describes "measurement results of resistivity in the depth direction," Applicant notes that the resistivity as disclosed is 3×10^7 Ωcm near the substrate surface and 2×10^7 Ωcm at a depth of 80 μm (i.e., showing a change of as much as 50%). Again,

one skilled in the art would not find that these values indicate a uniform dopant concentration in the depth direction.

For at least this reason, Applicant respectfully submits that amended independent claim 1 is not obvious in view of the cited references, and stands in condition for allowance. As amended independent claims 2, 5 and 6 also include elements claiming the above-argued distinctions over the '996 Publication, Applicant further submits that amended independent claims 2, 5 and 6 are also allowable for at least this reason.

Amended independent claim 9 claims:

9. An indium phosphide crystal containing iron or tin as a dopant, wherein:

a direction of growth has a <100> orientation; and

an average dislocation density value on a (100) plane, which is perpendicular to said growth direction, is [[being]] less than 5000 cm^{-2}.

Applicant submits that none of the cited references teach or suggest the use of <u>iron or tin</u> as a dopant for reducing dislocation densities. For example, the '088 Publication discloses that:

> when the temperature gradient in the liquid sealant is 100 °C/cm or less, the effect of reducing dislocation cannot be achieved. In particular, <u>substantially no effect is achieved with</u> undoped, <u>Fe-doped or Sn-doped InP</u>.

(Emphasis added).

The '088 Publication only discloses that "industrial production of InP crystals containing S or Zn and having a low dislocation density and a high single crystal ratio can be facilitated." Therefore, Applicant submits that amended independent claim 9, which claims iron or tin as a dopant, is not obvious in view of the cited references and stands in condition for allowance. As amended independent claim 10 also includes elements claiming this distinction over the 'cited

references, Applicant further submits that amended independent claim 10 is also allowable for at least this reason.

In amended independent claim 13, Applicant claims:

> **13.** An indium phosphide crystal containing sulfur or zinc as a dopant and having a diameter of 100 mm or more, wherein:
>
> a direction of growth has a <100> orientation;
>
> an average dislocation density value on a (100) plane, which is perpendicular to said growth direction, is less than 5000 cm^{-2}.

Applicant teaches a method by which an InP crystal having zinc or sulfur as a dopant can be grown having a low dislocation density and a diameter of 100 mm or more. (see, e.g., page 5, lines 8 - 18 and page 11, line 13 - page 14, line 7 of Applicant's specification). Applicant respectfully submits that none of the cited references, alone or in combination, teach or suggest an InP crystal containing zinc or sulfur as a dopant, and having a low dislocation density and a diameter of 100 mm or more. Therefore, Applicant submits that amended independent claim 13 is not obvious in view of the cited references, and stands in condition for allowance. As amended independent claim 14 also claims an InP crystal having zinc or sulfur as a dopant, a low dislocation density and a diameter of 100 mm or more, Applicant further submits that amended independent claim 14 is also allowable for at least this reason.

In amended independent claim 17, Applicant claims:

> **17.** A method for manufacturing an indium phosphide monocrystal containing a dopant, comprising:
>
> placing a seed crystal, which has a <u>cross-sectional area of 15% to 98%</u> of a cross-sectional area of a crystal body, has an <u>average dislocation density of less than 5000 cm^{-2}</u> and has a <u>substantially constant cross-sectional area along a length direction</u>, at a lower end of a growth container so that direction of growth of said crystal is <100> oriented, said <u>growth container including a seed crystal housing</u>

region having a substantially constant cross-sectional area, a crystal body housing region having a cross-sectional area larger than that of the seed crystal housing region, and a tapering region between the seed crystal housing region and the crystal body housing region;

placing said growth container containing said seed crystal, indium phosphide raw material, dopant, and boron oxide in a crystal growth chamber, and raising the temperature to at or above the melting point of indium phosphide;

after heating and melting boron oxide, indium phosphide raw material, dopant, and a portion of said seed crystal, lowering the temperature of said growth container in order to grow a monocrystal with a <100> orientation in a longitudinal direction of said growth container.

(Emphasis added)

The '987 Publication discloses a crystal growth method in which a conical seed crystal is used (see, e.g., FIGs. 4, 5 of the '987 Publication). Thus, and in sharp contrast to Applicant's claimed method of amended independent claim 17, the '987 Publication fails to teach a method for manufacturing an InP crystal in which a seed crystal is used that has a substantially constant cross-sectional area along a length direction.

According to the present invention, it is important that any gap between the seed crystal and the growth container is not excessively wide, as the melt in this case may enter this gap to solidify and thereby degrade the quality of the crystal. The p-BN crucible disclosed by the '987 Publication is described as having a bottom 18 with a lower part having an inner diameter of 76 mm, an upper part with a diameter of 82 mm, and a height of about 180 mm (see, e.g., page 3 of the English translation of the '987 Publication). Thus, and in sharp contrast to Applicant's claimed method, the '987 Publication fails to teach a seed crystal housing region having a substantially constant cross-sectional area. Moreover, to avoid the above-described problem resulting from melt entering the gap between the seed crystal and the seed crystal housing, the seed crystal used as described above must have a conical shape.

Applicant notes that it is extremely difficult to process a hard, brittle InP crystal into such a conical shape. Applicant discovered that a high quality InP crystal with low dislocation density could be obtained by using a seed crystal having a cross-sectional area of 15% to 98% of a cross-sectional area of a crystal body and a substantially constant cross-sectional area along a length direction.

The Examiner submits that both the '987 Publication (FIG. 3) and Rudolph teach a crystal growth method using a seed crystal having a cross-sectional area of at least 15% as compared to the crystal body. Applicant submits in fact that each of these references teaches a cross-sectional area of the seed crystal is identical to the diameter of the cross-sectional area of the crystal body.

For example, page 43 of Rudolph discloses that:

> a modified liquid encapsulated vertical Bridgman (LEVB) arrangement with a flat-bottom crucible and seed of the same diameter was applied successfully. Twin-free <100>-oriented InP single crystals with diameter of 50 mm and length of about 60 mm were grown reproducibly. In undoped crystals the etch pit density (EPD) has been measured to be (8 to 10) x 103 cm-2 in the front and middle region, markedly lower than in LEC [liquid encapsulated Czochralski] crystals.

Applicant submits that LEC methods are known for producing crystals having a high dislocation density, and that neither Rudolph nor the '987 Publication provide any teaching for specifically reducing dislocation densities can as compared to conventional vertical growth methods (i.e., using a crucible with a tapered region) or to conventional LEVB methods.[1] Applicant further notes that the diameter of the crystal and crucible used in Rudolph's disclosed method is relatively small (50 mm) as compared to Applicant's method (see, e.g., claim 32, claiming a crystal body

[1] Applicant notes that the '987 Publication notes the following advantages accrue from the approach of FIG. 3": "[as] described above, according to the single crystal growth method of the present invention ... (3) since no tapered part is provided, thermal stresses can be reduced and uniformity can easily be achieved, thereby realizing reduction of dislocation density, and (4) since no tapered part is provided, the thermal history can be easily made uniform and the properties can be made uniform." Applicant submits however, that because no theory or data is presented to demonstrate that such a reduction in dislocation density can in actuality be achieved, this assertion is speculative and represents merely "wishful thinking" on the part of the author of the '987 Publication.

diameter of "75 mm or greater"), as control of dislocation density becomes more for crystals having larger diameters.

As a result of significant experimentation, Applicant made the following discovery:

> when using a seed crystal having a cross-sectional area of 15% or greater, and preferably 50% or greater of the cross-sectional area of the crystal body, the dislocation density of the crystal largely depends on the dislocation density of the seed crystal. In order to obtain a dopant-containing InP crystal with an average dislocation density of less than 5000 cm^{-2} on the (100) wafer, or an average dislocation density of less than 2000 cm^{-2}, a seed crystal with a low dislocation density of less than 5000 cm^{-2} or less than 2000 cm^{-2} is preferably used. The present inventors have discovered that it is preferable to have a seed crystal with an average dislocation density lower than the target dislocation density of the crystal to be grown.

(Page 8, lines 4 - 14 of Applicant's specification, emphasis added)

As a result, Applicant discloses and claims a method for manufacturing an InP crystal with low dislocation density by using a seed crystal having a constant cross-sectional area of 15% to 98% of a cross-sectional area of the crystal body along a length direction, and which has a low dislocation density (i.e., "an average dislocation density of less than 5000 cm^{-2}). Applicant submits that neither Rudolph not the '987 Publication, alone or in combination, teaches or suggests a crystal manufacturing process using a seed crystal having the characteristics claimed by Applicant in amended independent claim 17. For at least this reason, Applicant submits that amended independent claim 17 is not obvious in view of the cited references, and stands in condition for allowance.

In summary, for at least the above-argued reasons, Applicants submit that amended independent claims 1, 2, 5, 6, 9, 10, 13, 14 and 17 are in condition for allowance. As claims 3, 4, 11, 12, 20, 21 and 23 - 37 each depend from one of allowable claims 1, 2, 5, 6, 9, 10, 13, 12 and 14, Applicant submits that dependent claims 3, 4, 11, 12, 20, 21 and 23 - 37 are also allowable for at least this reason.

Therefore, Applicant respectfully requests that the rejection of claims 1- 6, 9 - 14, 17, 20, 21 and 23 - 37 under 35 U.S.C. § 103(a) be withdrawn.

CONCLUSION

Each and every point raised in the Office Action has been addressed on the basis of the above amendments and remarks. In view of the foregoing, it is believed that claims 1- 6, 7, 9 - 14, 17, and 20 - 37 are in condition for allowance, and it is respectfully requested that the application be reconsidered and that all pending claims be allowed and the case passed to issue.

If there are any other issues remaining which the Examiner believes could be resolved through a Supplemental Response or an Examiner's Amendment, the Examiner is respectfully requested to contact the undersigned at the telephone number indicated below.

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Respectfully submitted,

By [signature]

Thomas J. Bean
Registration No.: 44,528
P.O. Box 770
Church Street Station
New York, New York, 10008-0770
(212) 527-7700
(212) 527-7701 (Fax)
Attorneys/Agents For Applicant